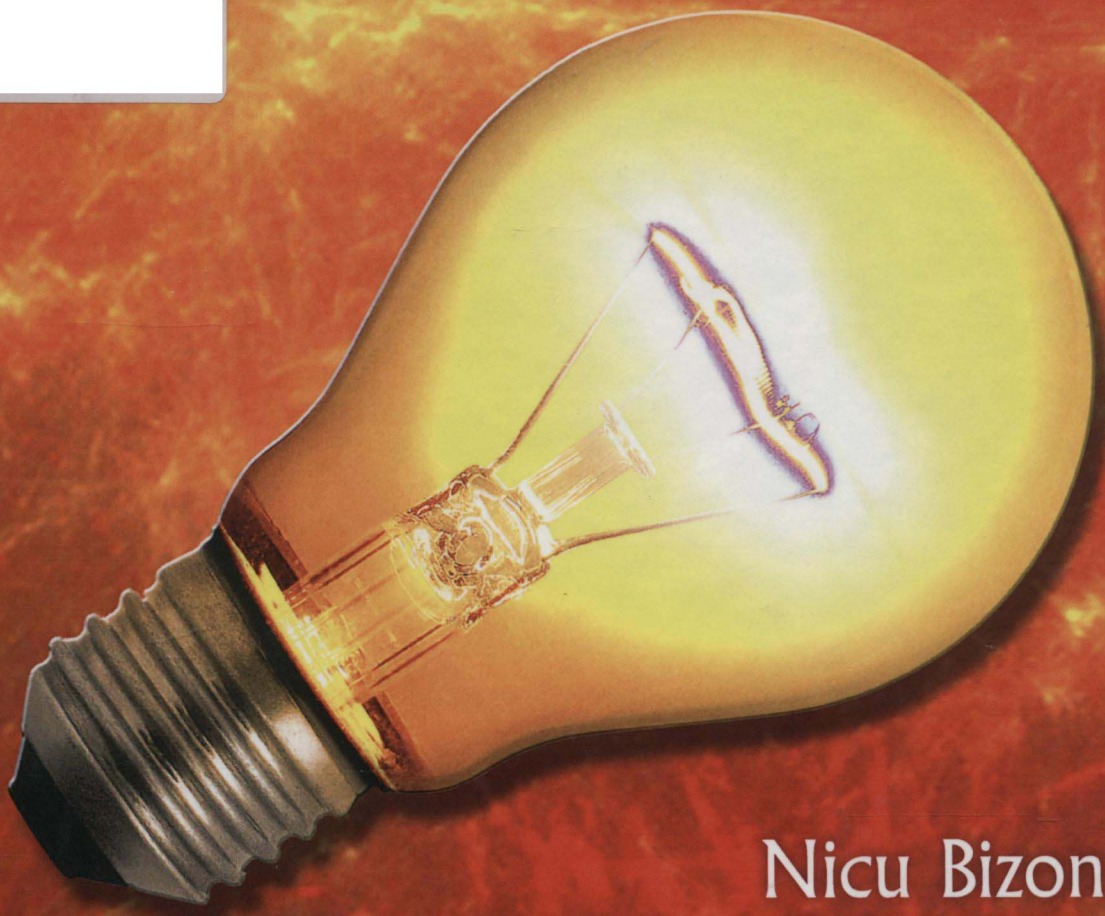
*Energy Science, Engineering and Technology*



Nicu Bizon
Naser Mahdavi Tabatabaei
Editors

# Advances in Energy Research

## Energy and Power Engineering

NOVA

ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

# ADVANCES IN ENERGY RESEARCH

## ENERGY AND POWER ENGINEERING

NICU BIZON
AND
NASER MAHDAVI TABATABAEI
EDITORS



nova publishers
New York

**LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA**

ISBN: 978-1-62257-534-3

*Published by Nova Science Publishers, Inc. † New York*

ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

# ADVANCES IN ENERGY RESEARCH

## ENERGY AND POWER ENGINEERING

# ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

Additional books in this series can be found on Nova's website under the Series tab.

Additional e-books in this series can be found on Nova's website under the e-book tab.

*Dedicated to all our teachers and colleagues who enabled us to write this book, and our family and friends for supporting us all along*

# FOREWORD

Electric power engineering occupies the most dominant role in provision of the population with the energy. The electric power more and more penetrates into human life and is used to supply people with important for life and survival elements including heating and air conditioning, cooking, lighting, access to mass media, security systems, telecommunications, operating capability of domestic appliances and other items important for survival.

The advantages of electric power and energy systems are universality and easily being converted into various other types of energy, easiness and cheapness of its transportation, accessibility for massive amounts of end users and practically capable to actuate directly all existing technical means.

Due to the high cost of energy, consumption improvement is very significant. Energy resources used in industries consist of electricity, water, natural gas, and other fuels and large industrial factories consume energy in a considerable scale. Therefore, energy consumption management plays an essential role in such places.

To study and develop the power systems, predictions of operation in electric networks using simulation methods are considered for analyzing and designing. The algorithms for forecasting the operation of the electric power systems with application of simulation methods are developed and applied.

The load growth always causes some problems in electric parameters at power grid. So these problems must be solved with different ways. One of these ways is application of distributed generation (DG) units and renewable energy resources so that voltage increasing and loss reduction are obtained.

Power quality is also important issues of distribution networks and one of the factors of losses in the network. Increasing electronic equipment changes current waveform in distribution networks and this can cause many problems. Harmonics is one of the most important power qualities in parameters of distribution networks.

The world intellectual control will play more and more actual role in energy-efficiency improvement, demand reduction, and better overall asset utilization. Such control can be effectively realized by wide application of smart grid technologies and devices. The analysis of smart grid concept is used for analyzing the intellectual reactive power and voltage control.

The above aspects are ilustrated in the this book by the editors and authors, in the following topics: optimal operation of power system; particle swarm optimization; design of power system stabilizer; distributed voltage control; nonlinear systems analysis; power

systems management; artificial intelligent methods; improving the power quality; photovoltaic systems; climate change factors; full cell inverter systems; hybrid power sources topology; hybrid electric vehicles; energy storage technologies; lighting technologies; luminescent solar concentrators; electric generation from waste heat; resources of bio-energy; renewable energy sources equipments; renewable energetic potentials; energy efficiency research; power distribution systems operation.

The book chapters and materials are very efficient in theoretical and application issues and are highly recommended for studying and considering in educational and research fields.

October 15, 2010

*Academician Arif M. Hashimov*
The First Vice-President
Azerbaijan National Academy of Sciences
Baku, Azerbaijan

# PREFACE

Engineering areas is an emerging theme for the 21 century, and the need for more energy resources and modern electric power systems are the critical part of the requirements. The electric power industry is more expanded worldwide now. New technologies leading to structural changes in the way that generation, transmission and consumption in power engineering area, are the emerging demands for electrical energy systems in the world, and increase attention being paid to the environmental impacts of power systems. Needless to say, the electric energy is essential for the development of industry and life, and high voltage engineering technology plays an important part in it. So, power electrical engineering must renew its content and methods in consideration of energy resources situation.

The traditional electrical power plants and also renewable energy systems with central and distributed stations are currently improved to be connected to the loads by interconnected transmission lines with cleaner and more environmentally being electric power resources. Therefore, distributed generation systems reduce transmission line losses and costs, but the potential to capture, utilize and minimize the waste and losses greatly increases their overall efficiency and economic advantages.

Power semiconductor devices are a key component of all power electronic systems. At least 50 percents of the electrical power consumption in the world is controlled by power devices in the areas of industrial, medical, and transportation sectors. The power devices have a major impact on the economy considering determining the cost and efficiency of power engineering systems. The power thyristors were developed for high voltage AC/DC transmissions and electric drives, the emphasis was on increasing the voltage rating and current handling capability. Meanwhile, the power transistors were developed with the goal of increasing the switching frequency in medium power systems.

There were clear missions to develop the AC/DC high voltage transmission system in power system networking. The basic research for designing ultra high voltage transmission lines were completed and the high voltage sections in the universities, research centers and also manufacturers were rapidly extended and many engineers and scientists in the field of high voltage engineering levels were activated. The universities have developed their power engineering programs and their graduates have become young researchers and professors in the field of energy systems and electrical power engineering. The researchers in the field of high voltage and power engineering moved gradually from the power engineering field to the fields of applications of discharge, plasma and high electric stress, such as the development of

new materials, industrial processes including material processing, chemical processing, food processing, electronic chip manufacturing, environmental control, bio-medicine and so on.

Artificial intelligence logics were introduced in the mid-sixties in order to mathematically formalize the treatment of imprecise notions and concepts found in almost every decision-making situation. After that, there has been a phenomenal increase in research activities aimed at implementing artificial intelligence concepts in many engineering applications and promote their usage in real-world applications such as in electric power systems. Most recently, there has been a tremendous surge in research and applications on applying computational intelligence methods in electric power engineering. Further, several methods are recently discussed for extracting information from test data and evaluating system performance.

Power engineering that is truly one of the main pillars of the modern civilization has also been a multidisciplinary field in terms of numerous applications of different subjects. These fields are in linear algebra, electronics, and signal processing to artificial intelligence including recent trends like bio-inspired computation, lateral computing and etc. to simplify the complex and nonlinear problems which requiring other complementary techniques and fields to solve them.

Advances in Energy Research: Energy and Power Engineering is a book aimed to highlight the above concepts and challenges by a systematic approach and, therefore, to provide understanding on how the electrical power engineering influences the energy efficiency conversion from energy resources to customers, in flow of generation and transmission, and the ways of controlling different systems by using different research methods.

A large number of specialists are joined as authors of the book chapters to provide their potentially innovative solutions and research related to advanced researches in energy and electrical power engineering, in order to be useful in developing new ways in energy network technologies, design and operational strategies. Several theoretical researches, case analysis, and practical implementation processes are put together in this book that aims to act research and design guides to help the postgraduates and researchers in electrical power engineering and energy systems. In particular, the specific purposes of the subjects are also including as knowledge base and applications used by undergraduates regarding to indicating research fields and innovative solutions as the challenges and opportunities for solving the problems.

The book presents significant results obtained by leading professionals from the industry, research and academic field, can be useful to the variety of groups in specific areas analyzed in this book. All works contributed to this book are new, previously-unpublished material or extended version of published papers in the proceedings of international conferences and transactions on international journals.

*Part I. Advances in Power Engineering*

The five chapters in Part I present the advanced theories and applications in electrical power engineering considering different operating cases. The topics in this part are including the advanced methods and applications in electrical power systems and networks related to the fields of distribution systems optimal operation and planning, particle swarm optimization and artificial bee colony algorithms, power system stabilizer designing, distributed voltage control, and analyzing HVAC-HVDC nonlinear systems.

Chapter 1 introduces the optimal planning of large-scale distribution networks as a multiobjective combinatorial optimization problem and discusses about the optimal distribution system planning (ODSP), in an electric distribution network regarding to new trends such as use of geographic information system (GIS) and application of distributed generation (DG) in distribution systems. The chapter includes some important objects related to mid and long terms load forecasting in distribution system, optimal MV substation placement, optimal feeder routing, optimal HV substation placement, optimal distribution system planning and optimal switch placement. Besides, the chapter introduces a GIS based ODSP expansion planning procedure and discusses about the requirements of the ODSP using GIS and DG's in ODSP.

The applications of artificial intelligence based optimization algorithms for power system control is given in Chapter 2. Artificial bee colony (ABC) algorithm and particle swarm optimization (PSO) algorithm as recent population based heuristic optimization algorithms are discussed and compared with each other. The algorithms in the chapter are related to tuning the parameters of the controllers in load frequency control (LFC), automatic voltage regulation (AVR) and power system stabilizer (PSS) applications, as well as the tuning superiorities of the algorithms are investigated and interpreted.

Chapter 3 presents an overview of the multiobjective design of power system stabilizers (PSSs) using heuristic methods such as genetic algorithms (GA) and particle swarm optimization (PSO) techniques. The chapter also investigates the optimal setting of the widely used conventional lead-lag PSS and its parameters tuning problem for converting to multiobjective function optimization solved by the mentioned heuristic methods. The design process takes into account a wide range of operating conditions and system configurations to ensure the robustness of designed PSS on a single-machine infinite bus and multi-machine power systems under different operating conditions and disturbances.

The logical controllers used for load tap changing transformers (LTCs) or capacitor banks (CBs), and discrete logics such as over excitation limiter (OXL) into continuous dynamics of the electrical power systems are described in Chapter 4. The chapter also presents an efficient hybrid framework for modeling and simulation of power systems in the coordinated voltage control using Modelica as a general-purpose object-oriented language. The chapter shows that uncoordinated interactions of local controllers caused by a major disturbance bring about many voltage collapse incidents occurrence in electric power system. The proposed hybrid framework is used in distributed model predictive control (D-MPC) and applied to designing a model-based feedback controller aiming at coordinating different control actions. The distributed MPC controllers prevent and postpone voltage collapse in circumstances of simulation results on a 12-bus power system.

The concept of HVDC network based on voltage source converter (VSC) as a new transmission technology is introduced in Chapter 5 with attractive technical advantages compared to the conventional HVDC, and dynamic voltage support for enhancing stability. The application of a supplementary controller along with the VSC HVDC to damp low frequency oscillations and to improve the dynamical and transient stability in power system has been also discussed in the chapter. The nonlinear equations of power system are applied and then linearized on a typical HVAC-HVDC system including a synchronous machine in order to obtain the linear state space model. The method of singular value decomposition (SVD), relative gain array (RGA) and damping function are used to measure the controllability of the electromechanical mode from each of the input signals. The chapter also

uses a damping controller based on adaptive neural network to increase dynamical and transient stability having good performance on damping of low frequency oscillations that usually appear in Electrical Power system.

*Part II. Issues of Power Quality and Energy Management*

The second part of this book tries to highlight in six chapters the crucial role of power electronics regarding the monitoring of energy quality via energy management systems and appropriate electronic equipments. The topics in this part are including the subject of software agents in managing electric power systems, applications of artificial intelligence methods in power engineering systems, applying the active filtering control for improving the power quality, environmental effects on photovoltaic systems, application of climate change factors to the loss of electrical distribution and transmission networks, and introducing the cycloconverters as an energy efficient topology for fuel cell inverter systems.

Chapter 6 is entirely highlighted on the application of software agents in managing electric power systems using multi-agent system (MAS). The chapter denotes to the MAS technology as range of applications including diagnostics, condition monitoring, power system restoration, market simulation, network control, and automation which are being migrated to gain experience in the use of MAS. The chapter also discusses about growing awareness of the multi-agent systems technology in industrial partners and their role in power engineering. The chapter confers the agents' structure, types, functions and the related themes. Then main management tasks of electric power systems including diagnostics, condition monitoring, power system restoration, market simulation, network control and automation are also demonstrated. The chapter also covers the actual use of software agents in managing the electric power systems and then shows some case studies of MAS power systems.

The application of the artificial intelligence methods such as genetic algorithms, fuzzy regression and their combinations applications in power engineering are focused in Chapter 7 in the areas of the electric power systems optimization, management and control. The chapter also shows the modeling and mechanisms of the methods in mathematical point of view and using the optimization methods joining features of probabilistic and deterministic optimization algorithms. The chapter also describes that the complexity of the power engineering problems in optimization and control aspects such as load flow problem, economic load dispatch, reactive power planning, transmission network expansion etc. are simply modeled and solved by the artificial intelligence methods.

Chapters 8 provides the effects of the voltage unbalancing in the power distribution systems due to nonlinear unbalanced electronic equipments and also large single phase electric charges. The chapter presents the unbalancing and voltage disordering effects on the sensitive charges in the industries which should be modified regarding to promotion of power quality issues. The chapter also confers the useful method based on series active filter as the simple and low cost advantages to overcome unbalancing and voltage disordering and improve voltage quality. It is demonstrated that the voltage unbalancing in faulted lines, voltage harmonics in the network, and compensating the voltage lose in transmission lines are improved using the simulating result in MATLAB.

Chapter 9 presents the photovoltaic (PV) modules sensitivities related to environmental factors such as temperature, irradiance and shading. The chapter is also describes developing of photovoltaic market and the electrical models of solar cells regarding to implementations

of photovoltaic systems as well as the impacts of environmental factors on photovoltaic systems. The large PV installations are utilized in distributed power generation schemes to overcome to the completely or partially shadowed PV modules due to passing clouds, neighboring buildings and towers, trees, etc. The PV characteristics get more complex with multiple peaks during partially shaded conditions caused by clouds and except for temperature and irradiance. Finally, the simulation and experimental results verify the shading effects on photovoltaic panels.

The effects of climate changes on transmission and distribution electricity loss are discussed in Chapter 10 regarding to three climatic parameters including humidity, temperature and pressure. The selected regions of studies in the chapter are Germany, Netherlands, Poland, Iran, Saudi Arabia, and Australia. Five models participating in the EU-FP6 project, ENSEMBLES are used in the simulation process to represent climate parameters for time intervals 1980 till 1999. The results show that the increasing temperature and pressure of ambient air due to climate change will affect electricity loss in the countries are located in arid and semi arid areas. The chapter analyses that the temperature will be the main parameter affects on the electricity loss in the countries with hot and dry, or moderate, continental and maritime climate, while in countries with desert and semi arid conditions, humidity it will be the most important parameter. Therefore, the climate change will affect the electricity loss with different amount for all investigated countries.

In Chapter 11 some advanced topologies and efficient operation of fuel cell (FC) inverter systems to assure a high reliability are presented. The chapter shows the consideration of FC inverter systems used in distributed generation (DG) applications and vehicle applications. So, two cases of the operation conditions and the performance indicators for efficient operation and high reliability are defined. Then, a PWM cycloconverter topology with multiple-carrier control technique is analyzed in the chapter. The good performances of total harmonics distortion (THD) coefficient and PWM cycloconverter are shown by the simulation results.

*Part III. Advanced Research on Automotive System: Hybrid Topologies, Control and Diagnostics*

The third part of this book tries to highlight some advanced research issues in automotive systems including hybrid topologies systems and their control and diagnostics techniques in five chapters. The topics in this part are including the subjects about real-time remote vehicle diagnostics, active mitigation of inverter current ripple in hybrid power source (HPS) topologies, spreading of power spectrum in HPS topologies, intelligent control of hybrid electric vehicles, and technologies of energy storage and their application on transportation system.

Chapter 12 deals with current issues of real time remote diagnostics, maintenance and monitoring of the communicant vehicle. The chapter introduces the concept of real time remote vehicle diagnostics, and various electronic devices areas in the automotive industry. The chapter also presents the current automotive status, the current real-time diagnosis communication protocols, and the associated algorithms for remote vehicle diagnostics, maintenance and monitoring systems.

An advanced topology of fuel cell (FC) hybrid power source (HPS) is proposed in Chapter 13 with an efficient mitigation of inverter current ripple and high reliability of system. The chapter also defines operation conditions and performance indicators for efficient

energy conversion and high reliability of FC HPS using nonlinear control process. The other aspect is the hybrid energy storage system (ESS) as auxiliary low power DC source for improving the HPS energy management. Next, the future batteries' technologies used in vehicle ESS is introduced. The operation of buck converter using the HPS topology as active parallel filter is also analyzed in the chapter to mitigate the low frequency components of current ripple as well as acting a controlled current source (CCS) to injecting an anti-ripple current on common point of HPS and inverter system.

Chapter 14 presents some issues related to the electromagnetic interferences (EMI) in electric vehicle (EV) and also hybrid EV. A voltage-mode nonlinear control is designed for the FC hybrid power source (HPS) topology to improve the performance and durability of FC stack and reduce the EMI, and also stabilize the HPS output voltage at a low voltage ripple in a wide frequency band. The simulation results regarding to HPS model as a controlled voltage source (CVS) show good performances obtained in the frequency-domain and also the time-domain.

The Chapter 15 aims to provide a novel intelligent power management strategy for a hybrid electric vehicle (HEV) considering to optimize the power flow between hybrid power sources in different modes of HEV operation. The chapter utilizes a fuzzy based controller to distribute the power between the internal combustion engine (ICE) and electrical motor (EM). The role of the fuzzy controller is to regulate the ICE operation at optimal efficiency according to the road load and the battery state of charge (SOC). Using combining the individual component models and the controllers, a dynamic model is developed for the HEV system. The load-following performance and power management results for the HEV system are resulted in the simulation process.

The Chapter 16 introduces the view of future developments in energy consumption and also is focused on the analysis of energy storage technologies and applications in power electronics. The chapter presents the issues of power grid stability problems due to unexpected and irregular massive energy production in renewable sources such as photovoltaic plants. The chapter emphasizes that the energy storage operation for distributing energy production into time periods will limit the negative impact of the stability problem in the network, especially in transportation systems.

*Part IV. Applications and Case Studies*

The final part of this book including eight chapters considers some applications and case studies in the energy sector and electrical power engineering. The topics in this part are including the overview of lighting technologies related to evaluation of lighting performance and energy saving, the luminescent solar concentrators (LSC) as an alternative of renewable energy, electric generation based on thermoelectric module, bio-energy resources from the tropical rain forests, case study in development of equipments for renewable energy sources, case study in estimation of the renewable energetic potential, case study in energy efficiency research in cooling system, and study of power distribution systems of new aircrafts in view of electromechanical actuations.

Chapter 17 discusses about the overview of lighting technologies related to traditional bulbs and other types of lights such as halogens, low-consume lights, and fluorescent lights. The chapter analyzes the electrical aspects of lighting systems regarding to reducing electricity consumption, optimizing resources, maintenance and life period features. The LED lamps are the most outstanding advantage in reduction of energy consumption. The chapter

also denotes the fast developments of LED technology as a revolution in the lighting market. The comparison of LED bulbs and traditional bulbs considering to reduction of consumption power is also discussed in the chapter.

Chapter 18 describes the luminescent solar concentrators (LSCs) as the alternative energy production solution. The LSCs typically consist of glass or transparent polymer slabs, doped with organic dyes or quantum dots that act as luminescent centers. The aim of the chapter is also to accomplish a comprehensive overview of results obtained in the past years on the work performed of luminescent solar concentrators.

Thermoelectric power generator as a solid-state heat engine to convert a flow of heat into electricity is studied in Chapter 19. It is noted that the cooling or heating energies are also directly produced from electrical energy in this phenomenon. The chapter shows designing, fabricating and thermoelectric characteristics of the system. Thermoelectric modules as a thermocouple (p and n types) are typically designed from bulk thermoelectric elements with flat ceramic plates for heat extraction and dissipation from surfaces of solid bodies. The common thermoelectric materials are $Bi_2Te_3$, PbTe, SiGe etc. for different ranges of temperatures which $Bi_2Te_3$ compounds are extensively used in power generation and cooling or heating energy-conversion systems at ambient temperatures. Numerous theoretical models have been studied in the chapter for considering the effective parameters and properties. Crystal growth simulation discloses a variation in the measured values of the thermoelectric parameters. The chapter also discusses about two fundamental fabrication techniques to prepare the thermoelectric elements, crystallization method and powder metallurgy modes.

Chapter 20 introduces the Mahula as a deciduous tree commonly found in the tropical rain forests of Asian and Australian continent. The flowers of this tree contain a rich source (40-60% on dry weight basis) of fermentable sugars (glucose and fructose). The flowers and seeds of this tree have been very useful in Indian sub-continental economy and can be employed to produce bio-ethanol (from flowers) and bio-diesel (from seeds). The chapter studies on batch fermentation of Mahula flowers for ethanol production using free and immobilized (in agar and calcium alginate) cells.

Chapter 21 focuses on the technical parameters of the solar energy plants mainly parabolic, parabolic-trough and flat regarding to various technological processes. The chapter shows that the solar equipment testing for desalination of the Caspian Sea water by evaporating method. The chapter also provides energy and technical characteristics of heating accumulator, solar kitchen, PV accelerator and combined air heating collector-accumulator. The solar energy equipment is justified in the chapter due to the energy, ecological and other different validations.

In Chapter 22 the uncontrollable cutting of forest in a case study is discussed as a great deal of ecological problems. So, the ecological clean renewable energy sources have great possibilities for saving the environment and supplying energy demand. Therefore, the concrete zone in the case study is selected to study the renewable energy potentials and due to the measurements of combined renewable energies, including combined solar-wind-biogas power plants (CSWBPP) have been constructed and tested in the settlement located near the selected zone. The chapter results show that application of CSWBPP is effective for saving woodlands and according to the renewable energy sources measurements and CSWBPP's test, the renewable energy potential is enough to save the nature of the preserve. The results of the chapter also show that solar, wind and biomass energy potentials could be essential source for energy technologies in the case study.

The energy efficiency in cooling systems and the effects of energy saving due to energy labeling are illustrated in Chapter 23. The chapter discusses different climates in defined case study and explains their respective share of cooling, lighting, and base load. The chapter also focuses on the cooling load as peak load is affected by cooling systems including split cooler, evaporative cooler, package unit, cooling tower and air handling unit. The chapter also shows the energy labeling is defined based on domestic circumstances, and finally future energy savings and cost savings are estimated.

Chapter 24 provides all electrical aircraft objective and spacecraft designing concept have been used to increase subsystem modularity of the electro mechanical actuators (EMAs) while achieving the properties of weight reduction, better energy efficiency, and increased system availability. The chapter shows three types of system identification methods for the modeling and parameter estimation of EMAs in the monitoring and controlling processes. The methods are including extended Kalman filter (EKF) to estimate the parameters of the electro-mechanical actuator; adaptive robust EKF to presence of measurement faults; and fuzzy model identification using genetic algorithms (GA) for unavailable electromechanical actuator mathematical model. The chapter show the results of fuzzy model based on GA designing which applied on EMA.

The editors recommend book as suitable for dedicated and general audiences that includes the power system professionals, as well as researchers and developers of energy sectors and electrical power engineering community. It is expected that readers to be graduates of energy and power engineering degree programs having a basic mathematical background.

As a whole, the book covers both theoretical background and application examples in power systems, and special and professional fields of electrical energy systems in altogether. Because the subjects' area approached in this book is vast in itself, it has been a little bit hard to balance the theoretical and applicative aspects in each of the chapters, so efforts of editors have been made to well cover the essential topics of the book. Specific in-depth further studies are pointed to the dedicated intensive resources of the book subjects for interested readers. Meanwhile, the application and study cases are possibly selected with as much real implications.

Finally, the editors hope that this book will be helpful to undergraduate and graduate students, researchers and engineers, trying to solve energy and power engineering problems using modern technical and intelligent systems based on theoretical aspects and application case studies.